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A full-band voltage beam forming mode for the Murchison Widefield Array digital receiver

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Abstract. A digital receiver at the Murchison Widefield Array (MWA) processes signal from eight MWA tiles for a band between 80 and 300 MHz. The digitized outputs are processed in the digital receiver using a polyphase filter bank to get a 1.28 MHz wide sub-bands. During a normal operation, 24 such sub-bands (corresponding to a 30.72 MHz band) are selected and sent out for processing in an FX correlator. To facilitate sensitive targeted searches and fast transient observations with the MWA, the digital receiver is enhanced to form a new mode, where a voltage beam is formed across the 80 to 300 MHz band. The digital receiver's data path and the firmware logic are enhanced to achieve this mode. The enhanced digital receiver can phase the full-band signals from eight tiles to form the voltage beams at each station. Now, the development of this beamformer mode to the MWA digital receiver is complete, and the new functionality is being tested in the lab. We present here briefly an introduction, the implementation of the new mode, the current status and the future plans.

Keywords : Murchison Widefield Array – digital receiver – voltage beam – phased array – fast transient

1. Introduction

Many interesting astrophysical phenomena associated with the broadband fast-transients can be studied using the time domain data from the Murchison Widefield Array (MWA). The MWA is an international collaboration between Australian, New Zealand, US, and Indian institutions and the telescope is located within the radio quiet Murchison Radio-astronomy Observatory (MRO) in Western Australia (Lonsdale et al. 2009; Tingay et al. 2013; Bowman et al. 2013; Beardsley et al. 2012). Time-domain astrophysics is one of the four key science drivers of this telescope. The MWA offers unique sensitivity to study the slower transient population while maintaining sensitivity to a considerable fraction of the millisecond pulsar population. The MWA Correlator generates visibilities at 0.5 sec with 10 kHz resolution. A voltage capture system (capture + beamformer + processing) capable of providing higher time resolution data for the fast transient observation is already designed by the ICRAR[1]. However, to further aid the search for transients like: pulsars, RRATs, radio flares and the FRBs, and to support other interesting studies such as: radius to frequency mapping and tomographic study of the emission-cone regions in pulsars, a full-band voltage beam forming mode is desired (Deshpande et al. 2007).

We have developed an FPGA-based digital receiver for the MWA (Thiagaraj et al. 2014). The digital receiver is one among the many specialized subsystems constituting the signal pipeline for this telescope. The MWA digital receiver carries out the sampling, quantization and channelization of the analog signal streams from eight dual-polarized tiles (MWA antenna elements). There are 16 such digital receivers for the entire MWA. The channelization is achieved using a polyphase filter bank (PFB).

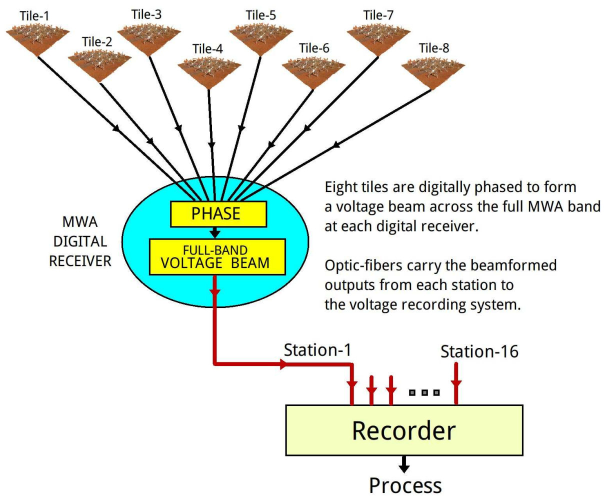

Figure 1. The MWA digital receiver is enhanced to incorporate a full-band voltage beam forming mode. The new mode forms a station beam at each digital receiver and transmit it through the optic-fibers to a voltage recording system.

The digital receiver is normally operated in a channel mode, where only 24 sub-bands corresponding to a total of 30.72 MHz band between 80 and 300 MHz is selected and sent out on optic-fibers to an FX correlator for further processing. We are now introducing a new mode to the digital receiver to facilitate getting the time-domain data across the entire MWA band (between 80 and 300 MHz).

2. Full-band voltage beam forming mode

After successful demonstration of the digital receiver operation in its default mode, we have attempted to enhance the digital receiver hardware and firmware to support the full band voltage beam forming mode. The new mode to the digital receiver is designed to provide complete compatibility with its existing modes that are used for the regular observations with the telescope.

In this beam forming mode, the required delays and phases are applied at the sampler and channelizer outputs respectively, in order to allow the signals from eight tiles serviced by the receiver to be coherently phased to produce a higher gain voltage beam with a narrow angular response over the entire MWA band. The reduction of 16 data pipelines to only two data streams, thus allows the full-band to be transmitted on

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the available three data fibers to the voltage capture system for recording. A schematic view of this new mode is shown in Figure 1.

Now, the development of this new mode is complete, and it is being tested in the laboratory and with an eight-tile system at the Gauribidanur observatory near Bangalore. After completing the field tests at Gauribidanur, we plan to test this mode at the MWA. Once the full-band voltage beam forming mode is operational with the Murchison Widefiled Array, we expect it to deliver new results in the area of low frequency, broad band, fast transients.

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